

SLEET AND ICE STORM AT CORPUS CHRISTI, TEX., DECEMBER 19-21 AND 25, 1924¹

By J. P. McAULIFFE

A sleet and ice storm of great severity, for this region, occurred at Corpus Christi, Tex., December 19, 20, and 21, 1924, and a much lighter fall was recorded on the 25th.²

More sleet fell in the severe sleet storm of 1897, but owing to the sparsely settled country at that time, less damage was sustained than in the present storm.

Rain began about 2.10 a. m. of the 19th; at noon the surface temperature sank to freezing, and within half an hour thereafter overhead wires, trees, shrubbery, streets, and sidewalks were covered with a heavy coating of glaze

making travel of all sorts difficult and dangerous. The coating on the wires and trees soon became so heavy as to cause the wires to break and branches of trees to collapse, while small ornamental trees and shrubbery were crushed to the ground. In rural districts the burden of ice caused telephonic communication to cease about 3 a. m. of the 19th, but it was not interrupted in the city until later in the day.

The storm persisted intermittently from the 19th to the 21st, during which time 0.3 inch snow and 0.9 inch sleet fell practically all of which remained on the ground. On the morning of the 21st there was an inch of snow and sleet on the ground, a rare occurrence for Corpus Christi.

¹ Condensed from the original.—Ed.

² This sleet storm was rather general in southwestern Texas on December 19-20. It was due to the same meteorological conditions that produced the Missouri-Illinois storm described in the immediately preceding note.—Ed.

THE SQUALL CLOUD IN A THUNDERSTORM; A DIRECT OBSERVATION OF ITS MOTION.

551.515 : 551.576

By DAVID L. WEBSTER

[Stanford University, Palo Alto, Calif., January 13, 1925]

In the very interesting discussion of thunderstorms given by Dr. W. J. Humphreys in his "Physics of the Air," the explanation of the squall cloud, or roll scud, is especially significant because that cloud is often so different in appearance from the main mass of cumulus clouds above it, and because its explanation as a result of interaction between the upward and downward currents is such a neat confirmation of the general theory. Because of these facts, direct observations of the motion in such a cloud are of some interest. As Doctor Humphreys informs me that records of such observations are quite rare, and I happen to have had an exceptional opportunity to make one, I venture to contribute this note in confirmation of the theory.

The occasion for this observation was a cross-country flight in October, 1918, in which Professor, then Major, C. E. Mendenhall and I were over the lower Rappahannock River, Va., in a Curtis JN4H, a small but fairly powerful plane, just as a thunderstorm was getting well started. Having read Doctor Humphreys' description, and seeing a well-developed roll scud under the forward side of this storm, I decided to investigate more closely.

I had had some previous experience with the saw-tooth shaped points that often appear on the tops of fracto-

cumuli subject to overrunning winds, and had noted in them eddies with horizontal axes, that could roll an airplane flying through them remarkably suddenly. In fact, since there is plenty of room in which to recover equilibrium, such clouds make interesting opportunities for a form of safe and sane acrobatics different from those possible in still air. It appeared reasonable, therefore, to expect to confirm Doctor Humphreys' statement as to the probable rolling motions in the roll scuds, by flying into it at a small angle, so as to be headed almost along its axis, and seeing whether the airplane would likewise roll with it.

This expectation was not only confirmed, but confirmed to such an unexpected extent that the strain on the wings caused them to creak with a scream audible even through the roar of the motor. I promptly brought the machine up into a stall, to reduce the strain by reducing the air-speed, and dropped out of the cloud rolling with all the angular velocity that the most ardent upholder of this theory of thunderstorms could wish for.

The conclusion is that the theory is confirmed, as far as such an observation can confirm it, but that the experiment shares one characteristic with the famous thunderstorm experiment of Benjamin Franklin, namely, that its repetition is most decidedly inadvisable.

TEMPERATURE OF DEEP WATER

551.463

By W. J. HUMPHREYS

Obviously the temperature of deep water in any given case depends on the supply of heat in the body of water concerned at some previous time, and its subsequent gain and loss of heat. This gain by subsurface water is through conduction from the earth beneath, conduction from the warmer water above, absorption of residual insolation, exothermic, including biological, reactions, and forced convection due to currents and wave agitation. Conduction from the earth is negligibly small, save where the shore effects are relatively large, as in the case of a mere pond. Conduction from above to any considerable depth also is very slow, and the residual insolation energy beyond a few meters extremely small. The heat from animal metabolism and other reactions also clearly is negligible. There remains, then, only forced convection to carry any considerable amount of heat at all far and rapidly below the surface. This too, while

exceedingly effective through the first 20 meters or so in the case of medium and larger sized lakes and all other bodies of water of similar area, does not extend to great depths. In fact, owing to forced convection, the temperature of the water is practically the same to 20 meters, more or less, below the surface, and there abruptly changes. Below this discontinuity layer, temperature decreases more and more slowly with depth, and presently becomes substantially constant, however great the remaining depth. This deeper water, then, gets only a negligible amount of heat by conduction, insolation, or convection. That is, it is enclosed by thermally all but impervious walls.

On the other hand, the loss of heat by the deeper water can occur only through conduction, radiation, and the addition of still colder water. Loss of heat by conduction clearly can occur only when the upper, and

therefore lighter, water is the colder, hence only when the surface temperature is below that of maximum density. This loss is quite negligible from water at any appreciable depth. Loss of heat by radiation from deep water also is of no consequence. There is left, then, only the advection of still colder water as a possible means of decreasing the temperature of the lower portions of any body of deep water. Hence:

a. In all bodies of water that annually, or even occasionally, are ice covered over any considerable portion of their extent, the temperature, from the greatest depth to within a few hundred meters (often much less) of the surface should, it would seem, be practically constant, and that of maximum density.

And this, indeed, is the deep temperature of all oceans and of the various suitable lakes that have been explored.

b. If no portion of the water ever freezes or cools to the temperature of maximum density, that is, if the body of water be a deep lake in tropical or subtropical regions, we should expect, as before, constancy in the temperature of the deeper portions; not, however, the temperature of maximum density but that of the coldest portion of the surface wherever and whenever (barring rare and freakish extremes) that should occur.

Observational checks of this conclusion unfortunately are not at hand except in respect to Lake Tanganyika in Central Africa, Lake Atitlan in Central America, and the Red Sea. The first of these gives an excellent check since it lies nearly north and south, is over 400 miles long, and very deep—at least 1,277 meters. According to numerous observations and many soundings,¹ the surface temperature ranges from 26.3° C. at the end nearest the Equator to 23.3° C. at the opposite end, while that of the body of the water decreases from the average of 25.0° C. at the surface to the continuous temperatures 23.2° C. at the depth of 200 meters, and 23.15° C. at and beyond the 400 meter level. That is, the constant temperature of the deeper water is practically the same as the minimum temperature of the coolest part of the surface.

Lake Atitlan, roughly 22 miles long, also supports this conclusion. On February 12, 1910, the temperatures of this lake² were, surface, 19.6° C. (a little warmer, no doubt, than in January), 50 meters below the surface, and down to the 315-meter bottom, 19.2° C.

The temperature data of the Red Sea likewise are applicable in this case since through practically its whole length of 1,200 miles it is much deeper, in places 2,000 to 2,190 meters deeper, than its 82-meter connection with the Indian Ocean. The great body of the water in this basin therefore below the 200-meter level, say, if once appreciably colder, as it now is, than the minimum shoal temperature in the strait of Bab-el-Mandeb, must so remain for a long while.

Now, from such data as I have found on the subject, chiefly that obtained by the "Pola" expeditions,³ the minimum surface temperature of the northernmost, hence coolest, portion of the Red Sea, exclusive of the

shallow Gulf of Suez, discussed below, is about 21.5° C., and the maximum, in the southernmost portion, about 32° C. At and below the 100-meter level the temperature throughout the sea is nearly constant and uniform, and below the 700 meter-level quite so at approximately 21.5° C. These values hold also for the deep Gulf of Akaba. The northern portion of the Red Sea is saltier also, owing to abundant evaporation and practical absence of inflow, as well as colder, than the southern. Hence, both because more saline and because colder, the northern portion of the sea must furnish the deeper water of the entire basin. Furthermore, since the distribution of salinity varies but little, the maximum density, the condition that determines inflow to the deeper portions, occurs at or near minimum temperature.

As implied above, the narrow Gulf of Suez, 172 miles long, but only about 50 meters deep, requires special consideration in this connection. Here the temperature of the water when coldest is only 17° C. to 18° C. and that, too, from top to bottom. During summer, on the other hand, this water is warm throughout. These conditions are owing to the fact that the depth of this gulf is not great enough, as is that of the Gulf of Akaba and the Red Sea proper, to take care of the winter surface cooling without affecting the temperature of the bottom water.

But why, one asks, does not this coldest water drain out into the basin of the sea? Doubtless some of it does and some also in the summer when, though warm, the salinity is abnormally high owing to excessive evaporation. The mingling of these two seasonal flows necessarily gives deep water of an intermediate temperature that can not differ much from 21.5°. But such of these flows as do exist clearly are comparatively small in amount and, apparently, of such nature that so far as thermal effects are concerned we may regard the Gulf of Suez as being no part at all of the Red Sea.

As nearly then as we can infer from the data available, the temperatures of the Red Sea likewise support the conclusion that deep-water temperatures of any sea or lake, when higher than that of maximum density, is determined by, and substantially the same as, the annual minimum temperature of the coolest portion of its surface.

Hence, if climate has long been constant, presumably the deep-water temperatures of all tropical and semi-tropical lakes can be closely approximated by observing over a sufficient period their minimum surface temperatures, not, in any given case, of the surface as a whole, but of that considerable portion that gets coldest. Also when, as in the case of Lake Tanganyika, the minimum surface temperature and the abysmal temperature are the same, we may infer that for decades at least, if not centuries, the local climate has not been appreciably colder than it now is. On the other hand, a marked difference between these temperatures would indicate a relatively modern change in the local climate to warmer than formerly if the bottom water is colder than the surface minimum, or, quite recently (too recent for adjustment) to colder if the temperature of the deep water is noticeably higher than the surface minimum.

¹ Marquardson. *Mitteilungen aus den Deutsch. Schutzgebieten*, 29, p. 97, 1916.

² Juday, *Trans. Wis. Acad.*, 18, p. 244, 1915.

³ *Denkschrift*, K. K. Akad. Wiss. Vienna, v. 65, 1898, and v. 69, 1901.